CLAIM AMENDMENTS

This list of claims will replace all prior versions, and listings of claims in the application.

Listing of Claims

1. (Currently Amended) A method for cycling a pressure swing adsorption (PSA) system, said PSA system receiving a feed gas and emitting a purified product gas and an exhaust gas, said method comprising:

providing a plurality of vessels, each vessel including an adsorbent for adsorbing impurities in the feed gas, each vessel further including a feed end responsive to the feed gas and emitting the exhaust gas, and a product end that emits the product gas;

operating each vessel of the plurality of vessels in a production stage for a plurality of cycle periods, wherein operating the vessel in the production stage includes delivering the feed gas to the feed end of the vessel and drawing the product gas from the product end of the vessel;

operating each vessel of the plurality of vessels in a first equalization down stage following the production stage for at least one cycle period, wherein operating the vessel in the first equalization down stage includes coupling the product end of the vessel to the product end of an adjacent vessel that is at a lower pressure to lower the pressure in the vessel;

operating each vessel of the plurality of vessels in a second equalization down stage following the first equalization down stage for at least one cycle period, wherein operating the vessel in the second equalization down stage includes coupling the product end of the vessel to the product end of another adjacent vessel that is at a purge pressure to further lower the pressure in the vessel;

operating each vessel of the plurality of vessels in a blow-down stage <u>directly</u> following the second equalization down stage for at least one cycle period, wherein operating the vessel in the blow-down stage further reduces the pressure in the vessel to an exhaust pressure;

operating each vessel of the plurality of vessels in a purge stage following the blow-down stage over a plurality of cycle periods, wherein operating the vessel in the purge stage includes feeding reduced-pressure product gas into the product end of the vessel and emitting the exhaust gas through the feed end of the vessel;

operating each vessel of the plurality of vessels in a second equalization up stage following the purge stage for at least one cycle period, wherein operating the vessel in the second equalization up stage includes coupling the product end of the vessel to the product end of an adjacent vessel that is at a higher pressure to increase the pressure in the vessel;

operating each vessel of the plurality of vessels in a first equalization up stage following the second equalization up stage for at least one cycle period, wherein operating the vessel in the first equalization up stage includes coupling the product end of the vessel to the product end of another adjacent vessel that is at a higher pressure to further increase the pressure in the vessel;

operating each vessel of the plurality of vessels in a product pressurization stage <u>directly</u> following the first equalization up stage for at least one cycle period, wherein operating the vessel in the product pressurization stage includes pressurizing the vessel with product gas to a product pressure; and

operating each vessel of the plurality of vessels in the production stage following the product pressurization stage.

2. (Original) The method according to claim 1 wherein operating each vessel in the first equalization down stage includes operating the adjacent vessel in the second equalization down stage during the previous cycle period and operating the adjacent vessel in the first equalization up stage while the vessel is operating in the first equalization down stage.

3. (Original) The method according to claim 1 wherein operating each vessel in the second down equalization stage includes operating the other adjacent vessel in the purge stage during the previous cycle period and operating the other adjacent vessel in the second equalization up stage while the vessel is operating in the second equalization down stage.

4. (Original) The method according to claim 1 wherein operating each vessel in the second equalization up stage includes operating the adjacent vessel in the first equalization down stage during a previous cycle period and operating the adjacent vessel in the second equalization down stage while the vessel is operating in the second equalization up stage.

5. (Original) The method according to claim 1 wherein operating each vessel in the first equalization up stage includes operating the other adjacent vessel in the production stage during the previous cycle period, and operating the other adjacent vessel in the first equalization down stage when the vessel is operating in the first equalization up stage.

6. (Original) The method according to claim 1 further comprising operating each vessel in a third equalization down stage at the next cycle period following operating the vessel in the second equalization down stage and operating the vessel in a third equalization up stage during a cycle period just prior to operating the vessel in the second equalization up stage.

7. (Original) The method according to claim 6 further comprising operating each vessel in a fourth equalization down stage at the next cycle period following operating the vessel in the third equalization down stage and at a cycle period just prior to the blow-down stage, and operating the vessel in a fourth equalization up stage during a cycle period just prior to the third equalization up stage and just after the purge stage.

8. (Original) The method according to claim 1 wherein the plurality of vessels are coupled together through a plurality of open/shut valves.

9. (Original) The method according to claim 1 wherein the plurality of vessels are coupled together through a rotary feed valve and a rotary product valve.

10. (Original) The method according to claim 1 wherein the plurality of vessels are coupled together through a single rotary valve communicating with both the feed end and the product end of each vessel.

11. (Original) The method according to claim 1 wherein the PSA system purifies a reformate feed gas into a hydrogen product gas.

12. (Original) The method according to claim 11 wherein the hydrogen product gas is fed directly into a fuel cell.

13. (Original) The method according to claim 11 wherein the reformate feed gas contains less than 59% hydrogen.

14. (Original) The method according to claim 11 wherein the product gas recovers at least 70% of the hydrogen that is in the feed gas.

15. (Original) The method according to claim 11 wherein the product gas contains at least 95% hydrogen.

16. (Original) The method according to claim 11 wherein the product gas contains at least 99% hydrogen.

17. (Original) The method according to claim 11 wherein the product gas contains less than 1ppm of carbon monoxide.

18. (Original) The method according to claim 11 wherein a first adsorbent in the vessels is selected from the group consisting of zeolite 5A, zeolite LiX and combinations thereof.

19. (Original) The method according to claim 18 wherein a second adsorbent in the vessels is selected from the group consisting of activated carbon, activated alumina, zeolite 13X, zeolite 4A and combinations thereof placed at the feed end of the vessel so that the feed gas first passes over the second adsorbent before contacting the first adsorbent.

20. (Original) The method according to claim 11 wherein the adsorbents in the vessels remove carbon monoxide, carbon dioxide, nitrogen and water.

21. (Original) The method according to claim 20 wherein the adsorbents in the vessels remove one or more of the impurities from the feed gas selected from the group consisting of methane, ethane, propane, butane, ethylene, propylene, hydrogen sulfide and NH_3.

22. (Original) The method according to claim 11 wherein the PSA system operates at a pressure below 7 atmospheres.

23. (Original) The method according to claim 22 wherein the PSA system operates at a pressure between 3 and 5 atmospheres.

24. (Original) The method according to claim 11 wherein the PSA system operates at a temperature between 20 and 100° C.

25. (Original) The method according to claim 24 wherein the PSA system operates at a temperature between 60° and 100° C.

26. (Original) The method according to claim 1 wherein providing a plurality of vessels includes providing at least five vessels.

27. (Original) The method according to claim 26 wherein providing a plurality of vessels includes providing nine vessels.

28. (Currently Amended) A method for cycling a pressure swing adsorption (PSA) system, said PSA system receiving a feed gas and emitting a purified product gas and an exhaust gas, said PSA system including a plurality of adsorbent vessels, each vessel including an adsorbent for adsorbing impurities in the feed gas, each vessel including a feed end responsive to the feed gas and emitting the exhaust gas, and a product end that emits the product gas, said method comprising:

operating each vessel of the plurality of vessels in a production stage for a plurality of cycle periods, wherein operating the vessel in the production stage includes delivering the feed gas to the feed end of the vessel and drawing the product gas from the product end of the vessel;

operating each vessel of the plurality of vessels in at least one equalization down stage following the production stage for at least one cycle period, wherein operating the vessel in the equalization down stage includes coupling the product end of the vessel to the product end of another vessel that is at a lower pressure to lower the pressure in the vessel;

operating each vessel of the plurality of vessels in a blow-down stage directly following the at least one equalization down stage for at least one cycle period, wherein operating the vessel in the blow-down stage further reduces the pressure in the vessel to an exhaust pressure;

operating each vessel of the plurality of vessels in a purge stage following the blow-down stage, wherein operating the vessel in the purge stage includes feeding reduced-pressure product gas into the product end of the vessel and emitting the exhaust gas through the feed end of the vessel;

operating each vessel of the plurality of vessels in at least one equalization up stage following the purge stage for at least one cycle period, wherein operating the vessel in the at least one equalization up stage includes increasing the pressure in the vessel;

operating each vessel of the plurality of vessels in a product pressurization stage directly following the at least one equalization up stage for at least one cycle period, wherein operating the vessel in the product pressurization stage includes pressurizing the vessel with the product gas to a product pressure; and

operating each vessel of the plurality of vessels in the production stage following the product pressurization stage.

29. (Original) The method according to claim 28 wherein operating the vessel in the at least one equalization up stage includes coupling the product end of the vessel to the product end of another vessel that is at a higher pressure.

30. (Original) The method according to claim 28 wherein operating the vessel in at least one equalization up stage includes coupling the feed end of the vessel to the feed end of another vessel that is at a higher pressure.

31. (Original) The method according to claim 28 wherein operating the vessel in at least one equalization up stage includes coupling the product end of the

vessel to the product end of another vessel that is at a higher pressure and coupling the feed end of the vessel to the feed end of another vessel that is at a higher pressure.

32. (Original) The method according to claim 28 wherein operating the vessel in at least one equalization down stage includes operating the vessel in a plurality of consecutive equalization down stages to reduce the pressure of the vessel over more than one cycle period, and wherein operating the vessel in at least one equalization up stage includes operating the vessel in a plurality of consecutive equalization up stages to increase the pressure of the vessel over more than one cycle period.

33. (Original) The method according to claim 28 wherein the plurality of vessels are coupled together through a plurality of open/shut valves.

34. (Original) The method according to claim 28 wherein the plurality of vessels are coupled together through a rotary feed valve and a rotary product valve.

35. (Currently Amended) The method according to claim 28 wherein the plurality of vessels are coupled together through a single rotary valve communicating with both the ~~fee~~ <u>feed</u> end and the product end of each vessel.

36. (Original) The method according to claim 28 wherein the PSA system purifies a reformate gas into a hydrogen product gas.

37. (Original) The method according to claim 36 wherein the hydrogen product gas is fed directly into a fuel cell.

38. (Original) The method according to claim 36 wherein the reformate feed gas contains less than 59% hydrogen.

39. (Original) The method according to claim 36 wherein the product gas recovers at least 70% of the hydrogen that is in the feed gas.

40. (Original) The method according to claim 36 wherein the product gas contains at least 95% hydrogen.

41. (Original) The method according to claim 36 wherein the product gas contains at least 99% hydrogen.

42. (Original) The method according to claim 36 wherein the product gas contains less than 1 ppm of carbon monoxide.

43. (Original) The method according to claim 36 wherein a first adsorbent in the vessels is selected from the group consisting of zeolite 5A, zeolite LiX, and combinations thereof.

44. (Original) The method according to claim 43 wherein a second adsorbent in the vessels is selected from the group consisting of activated carbon, activated alumina, zeolite 13X, zeolite 4A and combinations thereof placed at the feed end of the adsorbent vessels so that the feed gas first passes over the second adsorbent before contacting the first adsorbent.

45. (Original) The method according to claim 36 wherein the adsorbents in the vessels remove carbon monoxide, carbon dioxide, nitrogen, and water.

46. (Original) The method according to claim 45 wherein the adsorbents in the vessels remove one or more of the impurities from the feed gas selected from the group consisting of methane, ethane, propane, butane, ethylene, propylene, hydrogen sulfide and NH_3.

47. (Original) The method according to claim 36 wherein the PSA system operates at a pressure below 7 atmospheres.

48. (Original) The method according to claim 47 wherein the PSA system operates at a pressure between 3 and 5 atmospheres.

49. (Original) The method according to claim 36 wherein the PSA system operates at a temperature between 20 and 100° C.

50. (Original) The method according to claim 49 wherein the PSA system operates at a temperature between 60 and 100° C.

51. (Original) The method according to claim 28 wherein providing a plurality of vessels includes providing at least five vessels.

52. (Currently Amended) A pressure swing adsorption (PSA) system for purifying a feed gas into a product gas, said system comprising:

a feed manifold responsive to the feed gas;

a product manifold outputting the product gas;

an exhaust manifold outputting an exhaust gas including impurities from the feed gas;

a plurality of vessels responsive to the feed gas from the feed manifold and outputting the product gas to the product manifold, said plurality of vessels including an adsorbent for adsorbing the impurities in the feed gas;

at least one feed valve coupled between the feed manifold and the plurality of vessels for controlling the feed gas applied to the vessels; and

at least one product valve coupled between the vessels and the product manifold for controlling the product gas drawn from the vessels to the product manifold, wherein the PSA system operates by a predetermined PSA cycle, said PSA cycle including operating each vessel of the plurality of vessels in a production stage for a plurality of cycle periods, wherein operating the vessel in the production stage includes delivering the feed gas to the feed end of the vessel and drawing the product gas from the product end of the vessel, operating each vessel of the plurality of vessels in a first equalization down stage following the production stage for at least one cycle period, wherein operating the vessel in the first equalization down stage includes coupling the product end of the vessel to the product end of an adjacent vessel that is at a lower pressure to lower the pressure in the vessel, operating each vessel of the plurality of vessels in a second equalization down stage following the first equalization down stage for at least one cycle period, wherein operating the vessel in the second equalization down stage includes coupling the product end of the vessel to the product end of

another adjacent vessel that is at a purge pressure to further lower the pressure in the vessel, operating each vessel of the plurality of vessels in a blow-down stage directly following the second equalization down stage for at least one cycle period, wherein operating the vessel in the blow-down stage further reduces the pressure in the vessel to an exhaust pressure, operating each vessel of the plurality of vessels in a purge stage following the blow-down stage over a plurality of cycle periods, wherein operating the vessel in the purge stage includes feeding reduced-pressure product gas into the product end of the vessel and emitting the exhaust gas through the feed end of the vessel, operating each vessel of the plurality of vessels in a second equalization up stage following the purge stage for at least one cycle period, wherein operating the cycle in the second equalization up stage includes coupling the product end of the vessel to the product end of an adjacent vessel that is at a higher pressure to increase the pressure in the vessel, operating each vessel of the plurality of vessels in the first equalization up stage following a second equalization up stage for at least one cycle period, wherein operating the vessel in the first equalization up stage includes coupling the product end of the vessel to the product end of another adjacent vessel that is at a higher pressure to further increase the pressure in the vessel, and operating each vessel of the plurality of vessels in a product pressurization stage directly following the first equalization up stage for at least one cycle period, wherein operating the vessel in a product pressurization stage includes pressurizing the vessel with product gas from the product manifold to a product pressure for the production stage.

53. (Original) The system according to claim 52 wherein the at least one product valve is a plurality of product valves, a plurality of purge valves and a plurality of equalization valves.

54. (Original) The system according to claim 52 wherein the at least one feed valve is a plurality of feed valves and a plurality of exhaust valves.

55. (Original) The system according to claim 52 wherein the at least one feed valve is a single rotary feed valve, and the at least one product valve is a single rotary product valve.

56. (Original) The system according to claim 52 wherein the PSA system purifies a reformate feed gas into a hydrogen product gas.

57. (Original) The system according to claim 56 wherein the hydrogen product gas is fed directly into a fuel cell.

58. (Original) The system according to claim 56 wherein the reformate feed gas contains less than 59% hydrogen.

59. (Original) The system according to claim 56 wherein the product gas recovers at least 70% of the hydrogen that is in the feed gas.

60. (Original) The system according to claim 56 wherein the product gas contains at least 95% hydrogen.

61. (Original) The system according to claim 56 wherein the product gas contains at least 99% hydrogen.

62. (Original) The system according to claim 56 wherein the product gas contains less than 1 ppm of carbon monoxide.

63. (Original) The system according to claim 56 wherein a first adsorbent in the vessels is selected from the group consisting of zeolite 5A, zeolite LiX, and combinations thereof.

64. (Original) The system according to claim 63 wherein a second adsorbent in the vessels is selected from the group consisting of activated carbon, activated alumina, zeolite 13X, zeolite 4A and combinations thereof placed at the feed end of the adsorbent vessels so that the feed gas first passes over the second adsorbent before contacting the first adsorbent.

65. (Original) The system according to claim 56 wherein the adsorbents in the vessels remove carbon monoxide, carbon dioxide, nitrogen, and water.

66. (Original) The system according to claim 65 wherein the adsorbents in the vessels remove one or more of the impurities from the feed gas selected from the group consisting of methane, ethane, propane, butane, ethylene, propylene, hydrogen sulfide and NH_3.

67. (Original) The system according to claim 56 wherein the PSA system operates at a pressure below 7 atmospheres.

68. (Original) The system according to claim 67 wherein the PSA system operates at a pressure between 3 and 5 atmospheres.

69. (Original) The system according to claim 56 wherein the PSA system operates at a temperature between 20 and 100° C.

70. (Original) The system according to claim 69 wherein the PSA system operates at a temperature between 60 and 100° C.

71. (Original) The system according to claim 52 wherein the plurality of vessels is at least five vessels.